North American Tropical Cyclone Landfall and SST

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- Tracer transport: mostly ocean, mostly observationally based, with applications to carbon uptake.

  GISS colleagues: Francesca Terenzi (APAM grad),
  Mark Holzer (APAM, Research Scientist)

- Tropical Cyclones: statistical analyses with emphasis on improving estimates of landfall risk.

  GISS colleague: Emmi Yonekura (DEES grad).

Tropical Cyclone Work:

- Lots of work on hurricane frequency and intensity (post Katrina!), but much less on changing (or not) landfall risk. (What is landfall risk?)

- Goal: Estimate changing hurricane risk along North-American coast (Emmi is starting NW Pacific analysis).

- Problem: Analysis of historical landfalls insufficient for local regions or for changes in risk with climate. Too few events.

- One approach: Build statistical “model” of TCs from birth to death. Much more data used than just landfall counts.

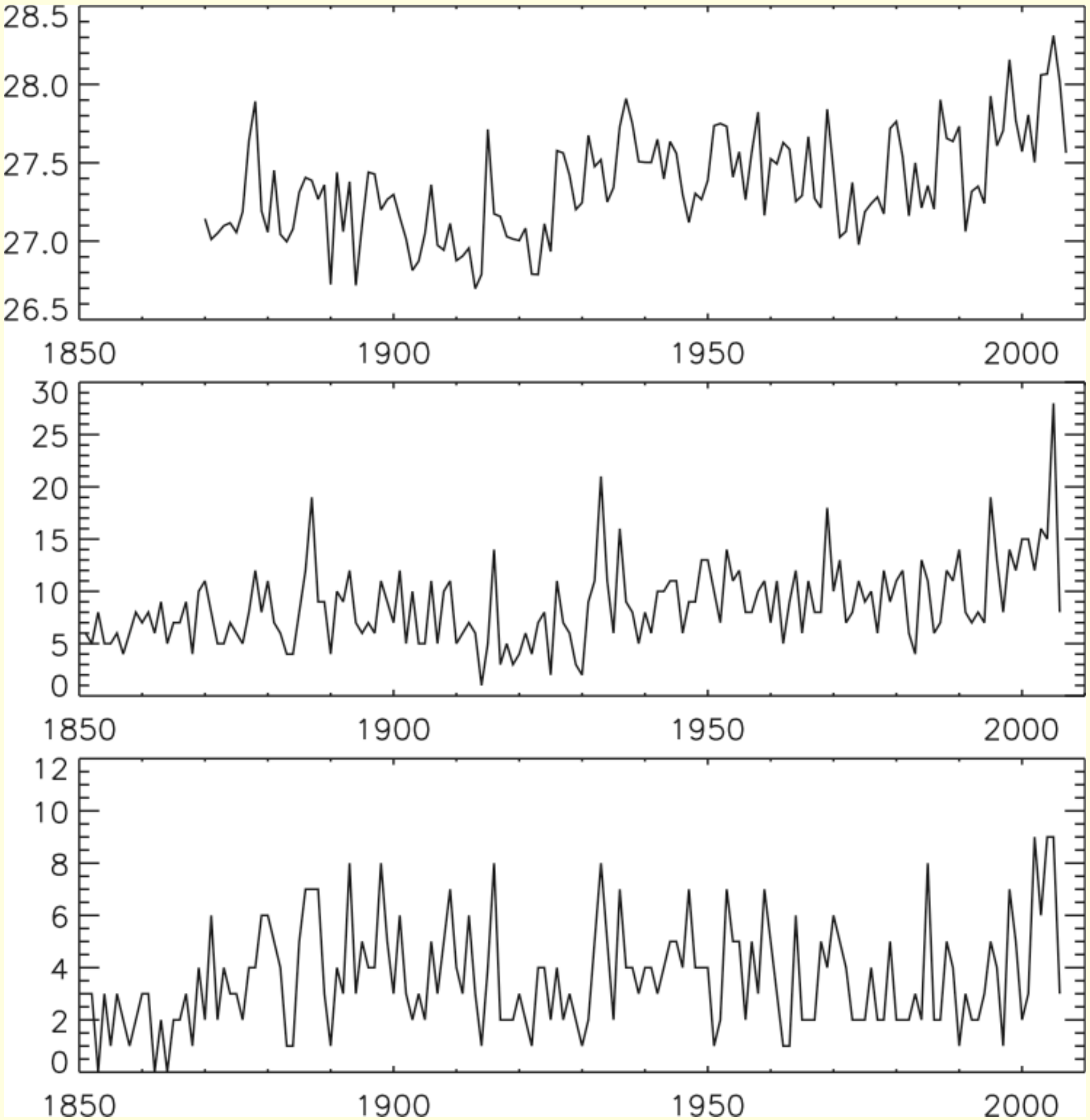
Model components: genesis, tracks, intensity. (Hall and Jewson, 2007; 2008)

Nitty-gritty applied meteorology; mostly statistical analysis.

Public-policy and private-sector applications.

Data: mostly NOAA’s NHC HURDAT “best track”

North-Atlantic Genesis: some time series



Annual TC counts (HURDAT best track)

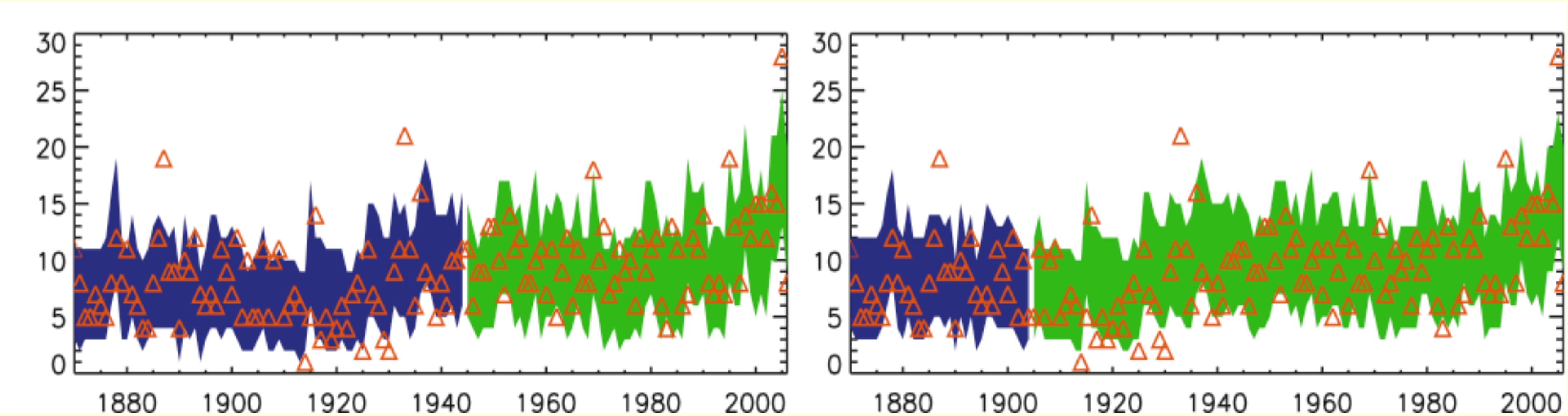
US landfalls computed from HURDAT TCs.

Note: small random fraction of TCs make US landfall. Degrades relationship with SST. Much worse if looking regionally.

Well known: North-Atlantic Frequency increasing with SST

$$f = \frac{\lambda e^{-\lambda}}{k!}$$

Annual count is Poisson. Poisson rate λ may depend on climate indices.
Poisson regression of counts on SST: $\lambda(t) = \exp(b_0 + b_1 \,\mathrm{SST}(t))$

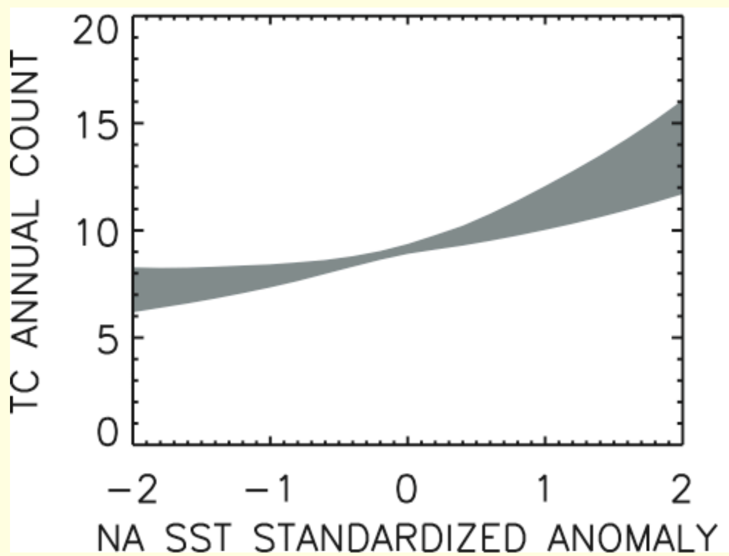


5% to 95% range of Poisson regression model of annual count, given SST.
Symbols: historical; Purple: model building years; Green: forecast years.

Shift of 0.6ºC ($-\sigma$ to $+\sigma$) explains 5.5 storms.
Robust to historical data set.

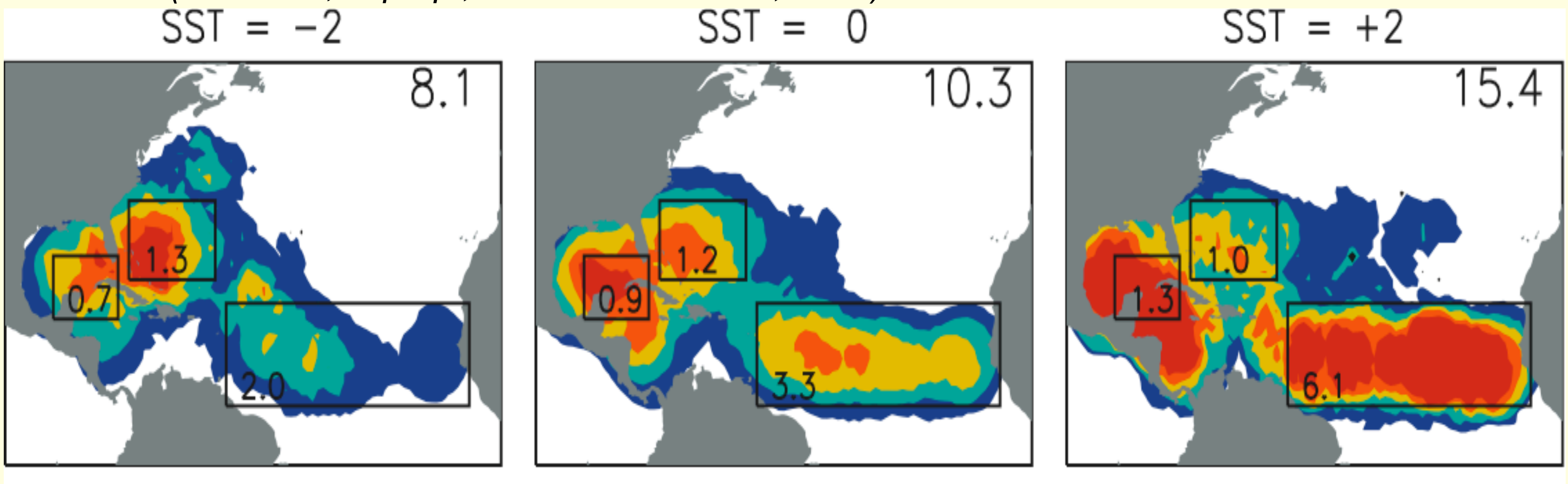
SST-count relationship tested on
Multiple 10% random data-year drop.

Note: no global SST-count relationship



Less known: the increase is not uniform

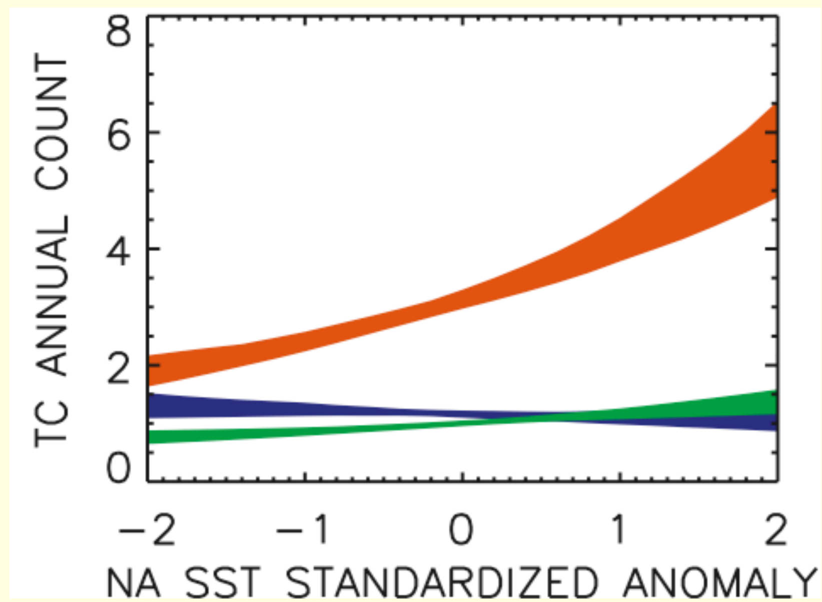
(Hall et al., in prep.; Kossin and Vimont, 2007)



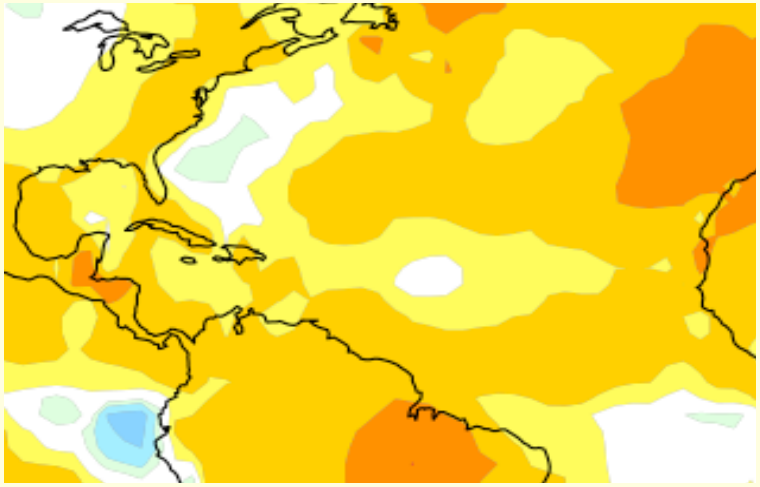
Perform similar Poisson regression, but now locally in overlapping data circles (but still using basin-wide SST). Scale optimized out-of-sample to max likelihood of data.

Sub-region counts versus SST. Range comes from repeated analysis with random 10% data drop.

Possible landfall impact: different genesis regions have different odds of making landfall.

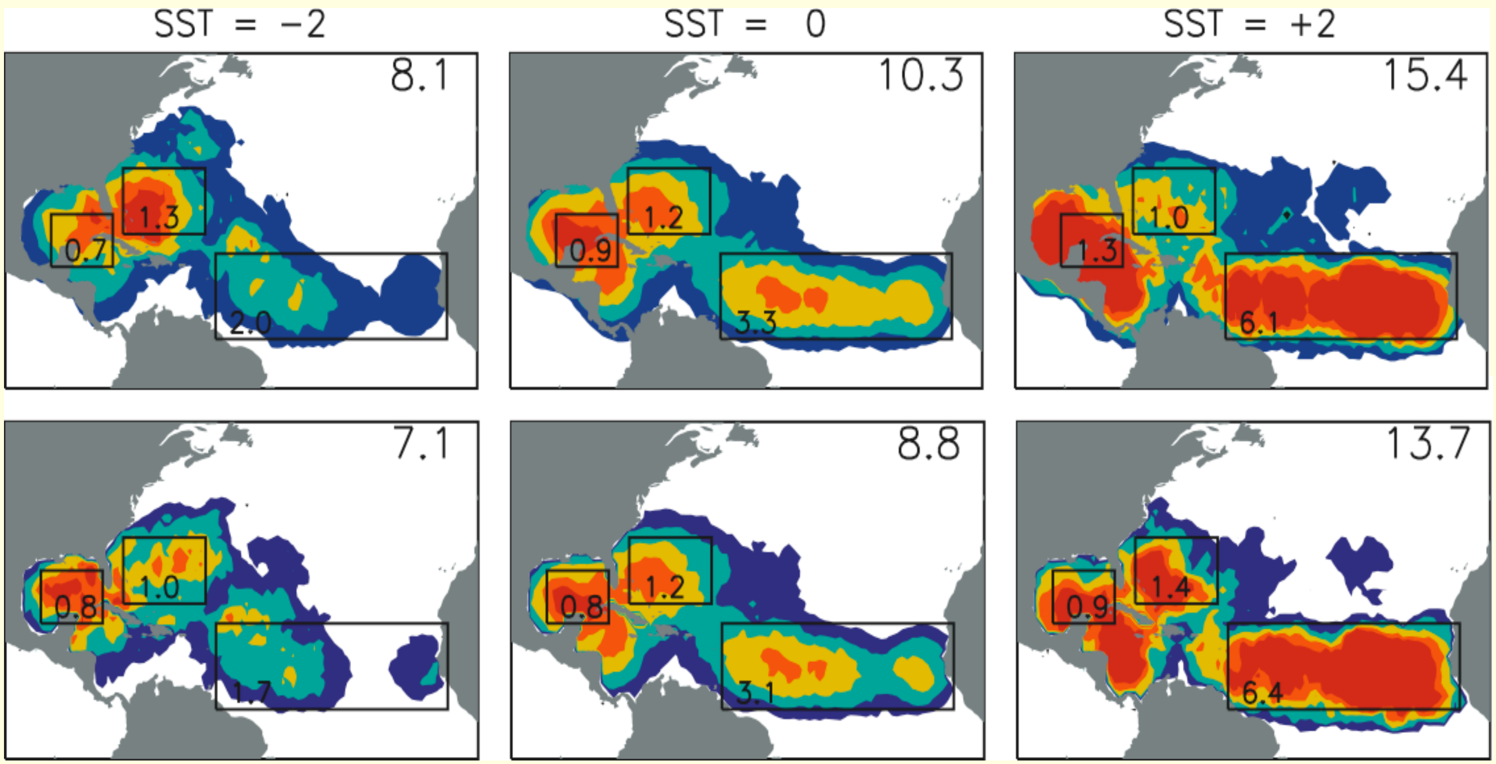


GISS website surface-T trend map (1970-2005)



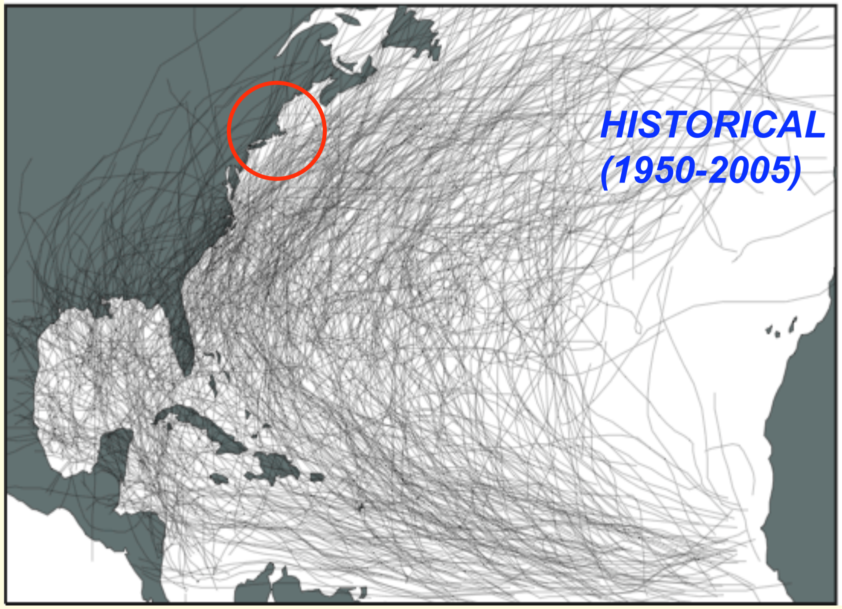
Why spatial non-uniform increase with SST?

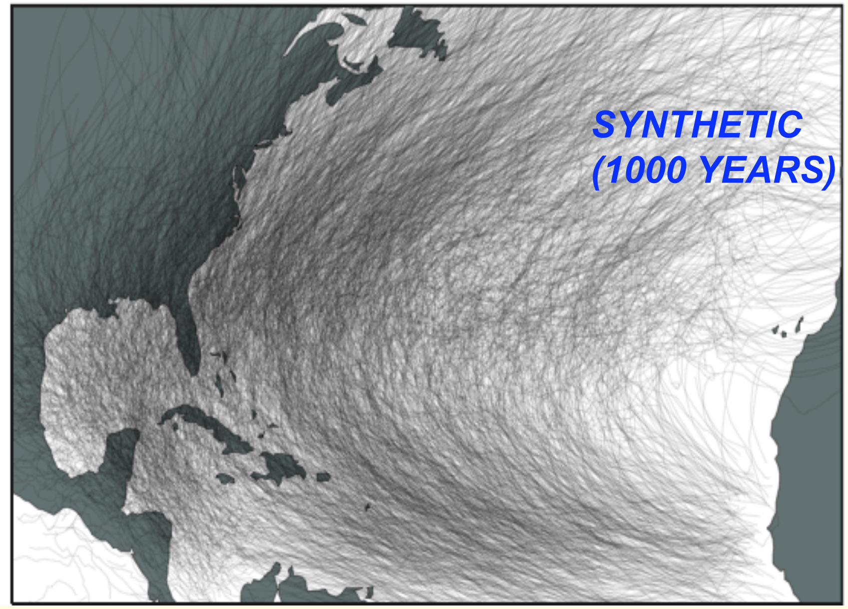
- Genesis increases everywhere with local SST.
- But, SST increases not uniform.
- Note Atl-dipole model (AMM) has SST signature.
- Kossin and Vimont (BAMS) point out AMM
  has wind-shear signal, affects genesis.

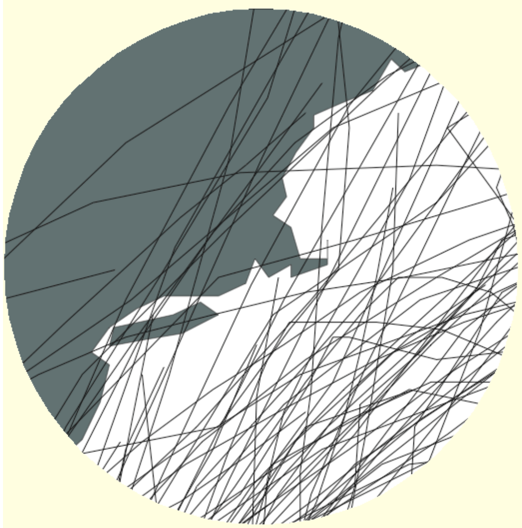


Same Poisson regression, but now using local SST (instead of basin-wide).

Relate genesis shift to landfall changes: storm tracks

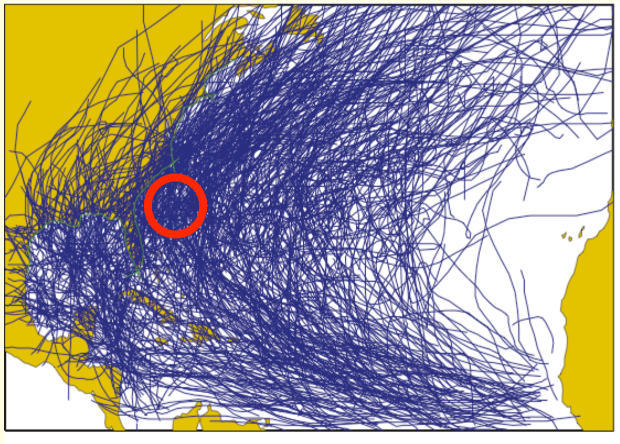




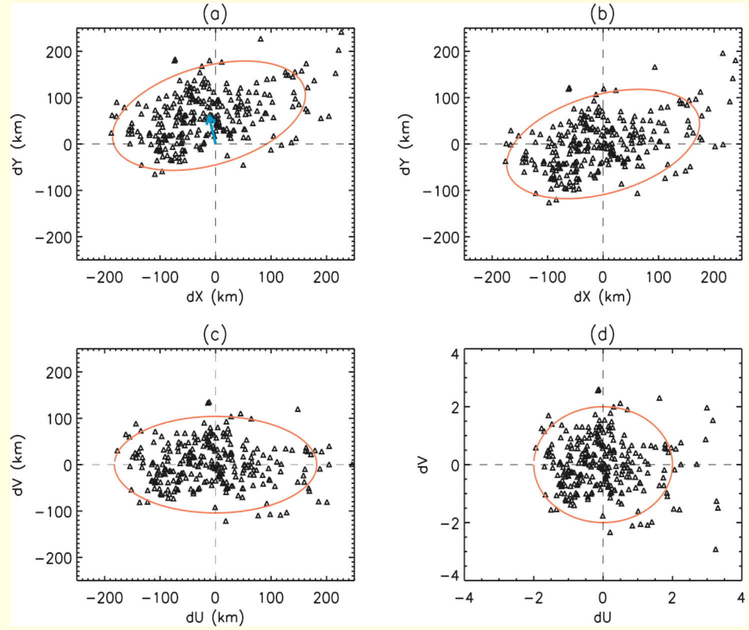


- *Landfall rare on many regions. How to estimate risk?*
- *Track model uses data from entire basin to compute landfall. More complete use of information than just local landfall events.*
- ***Near misses are informative!***
- *"Good" model: historical tracks are typical subset of synthetic tracks.*
- *Build in climate indices: SST, ENSO*

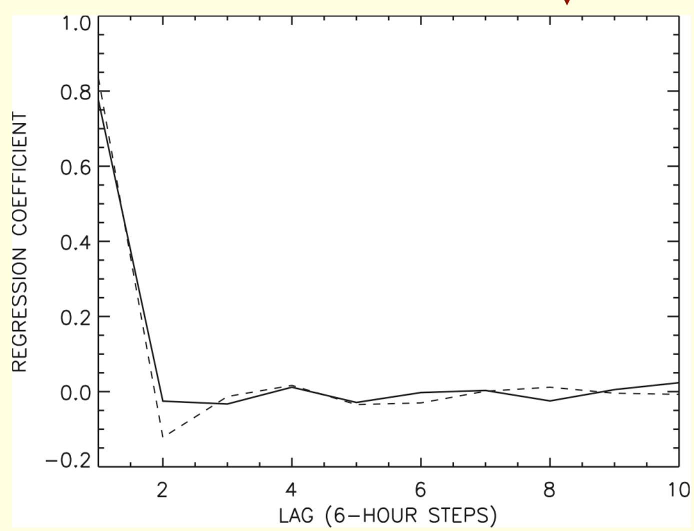
Simulating track increments:



dx, dy modeled with bivariate correlated Normal distribution.



Standardized du, dv errors independent. Each has high Autocorrelation at lag one.



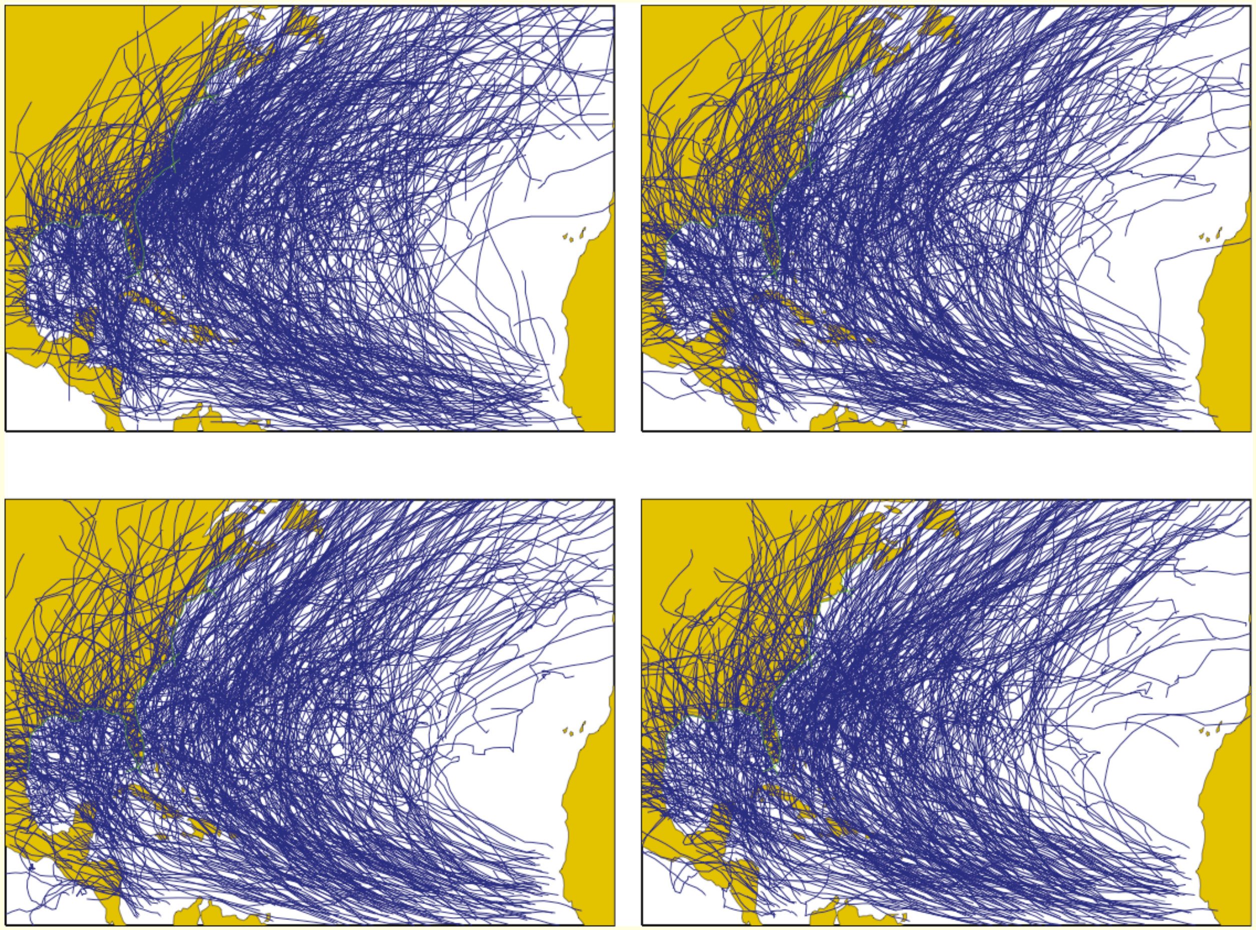
Model errors as AR(1)

$$u_i = c\, u_{i-1} + (1 - c^2)^{1/2}\, \varepsilon$$

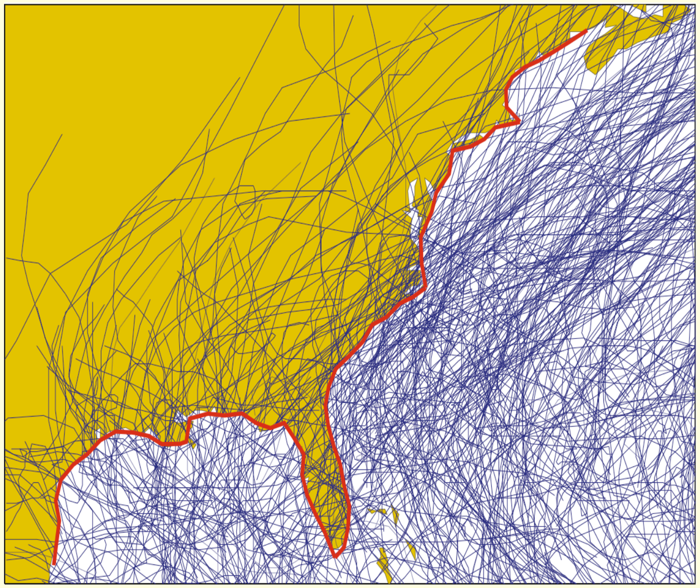
Convert back to dimensional x, y.

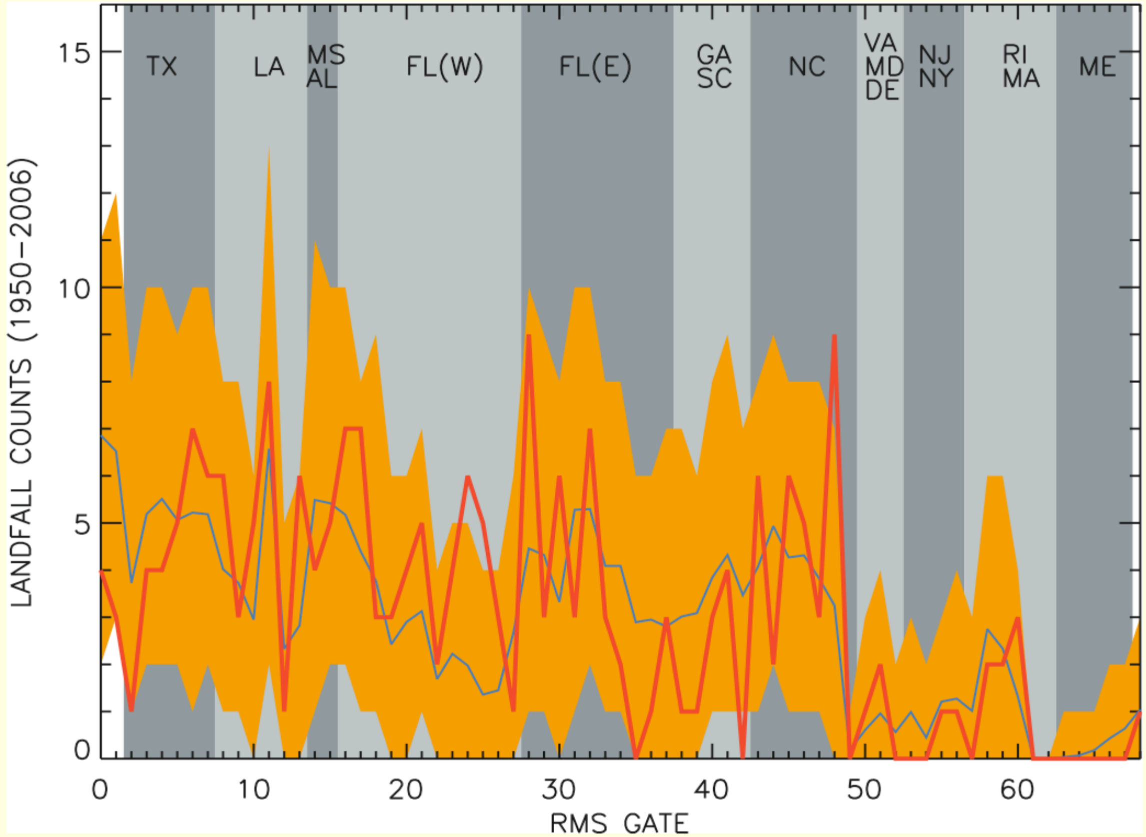
- Rescale u, v by rms variance
- Rotate to x, y coordinates
- Add x, y means

Historical 1950-2006 and three simulations of period



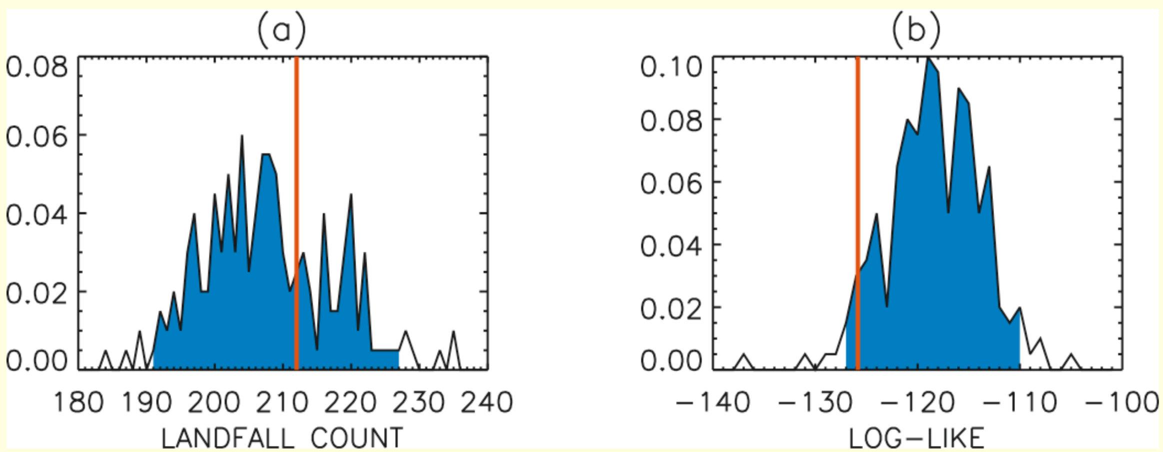
Model is doing well to extent that historical track set looks like typical sample of large ensemble of simulated track sets. “Like” by what measure?





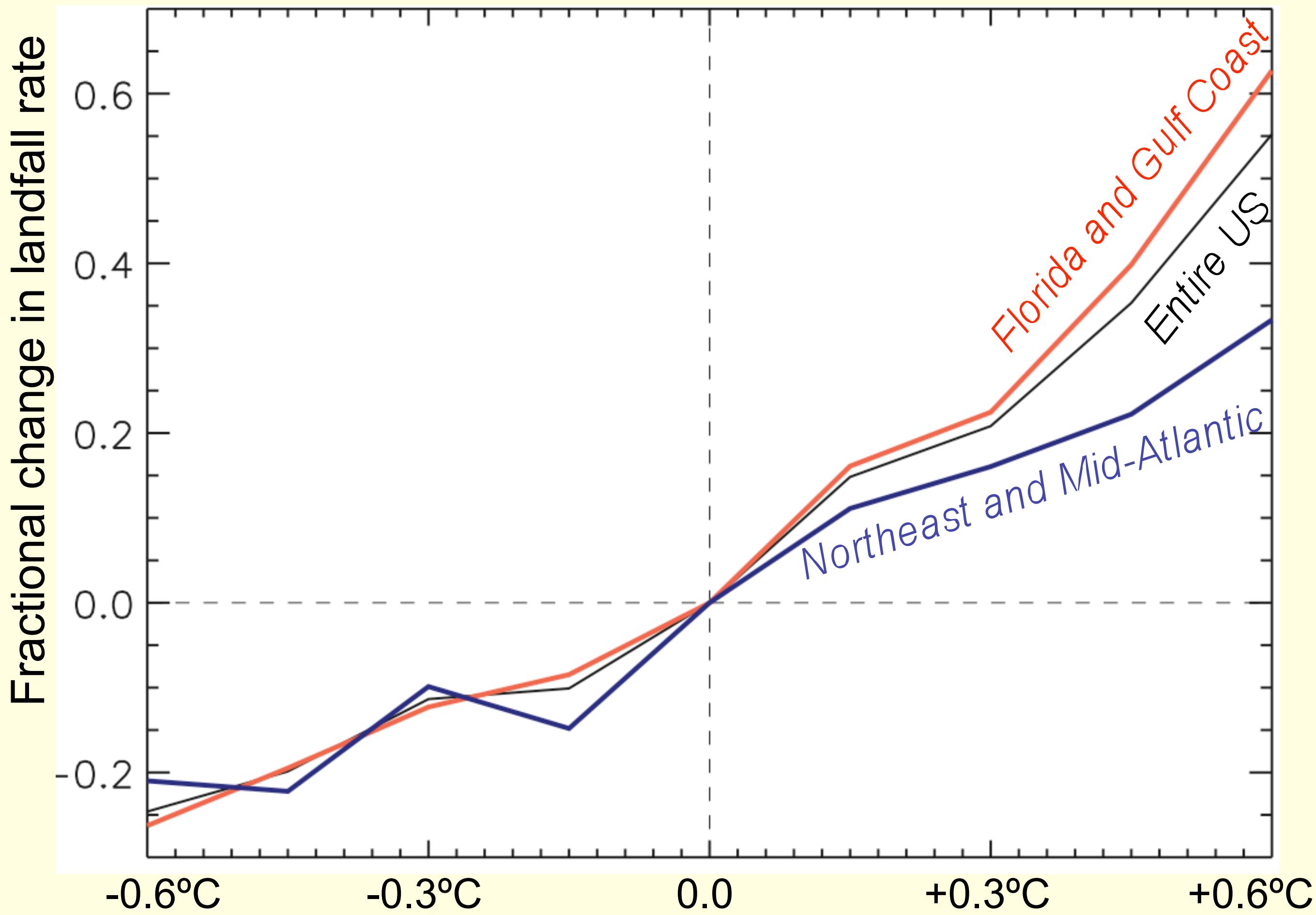
Landfall rates:
- 200 simulations.
- Count segment crossings.
- Compute mean rates.
- Compute 5%-95% band.

- Overall profile "good".
- Total count bounds historical
- Possible regional biases.



Assume Poisson landfall on each gate. Use ensemble-mean counts to get Poisson rate. Evaluate Poissons with counts from each ensemble member. Sum over coast to get a likelihood score for each member. Do same for historical landfall. Where does historical likelihood fall in simulation spread?

Multiple track simulations for genesis in range of SST values. Compute landfall …



Caveats: (1) Results for all tropical cyclones (not partitioned by intensity).
(2) Preliminary result … no proper uncertainty analysis yet.